# Normalized Metered Energy Savings (NMEC) Program M&V Plan

Appropriateness of Meter-Based Platform

Pursuant to the CPUC guidance issued on January 31, 2019, NMEC is approved for use in the commercial sector and TRC’s Agriculture Energy Savings Action Plan (ASEAP) Program will use a site-level NMEC approach as applicable, and will conform to the latest version of the Meter-Based NMEC Rulebook (currently ver.2.0). In the site-level NMEC approach, savings are determined for each program participant after measures are installed, based on an analysis of pre- and post-installation meter data. In this approach, the post-installation energy use data provides important feedback to assure savings are achieved. This aligns the goals of customers and ratepayers, who both require assurance of the return on their investments.

Site-level NMEC follows the well-known International Performance Measurement and Verification Protocol (IPMVP) Option C approach. Traditionally applied with billing data, this approach has been updated with advanced modelling methods applied to short-time interval data from California’s advanced metering infrastructure (AMI data), enabling much more accurate savings analysis. Our approach allows multiple advanced modeling algorithms and independent variables to be assessed, to find the best fitting model for any NMEC project. This enables the methodology to be applied over a much wider range of building use types.

Several attributes of our site-level NMEC approach make it a robust and appropriate methodology for both the program and its customers:

* The savings methodology aligns with how customers think of their savings investments: at the meter.
* The short-time interval data and savings analysis provides fast feedback on a project’s performance, enabling timely identification and resolution of issues that prevent savings.
* The approach focusses on achieving savings and verifying the return on the customer’s and the program’s investment.
* The method is scalable because it is applicable across multiple commercial building types within the Agricultural sector and its uniform approach enables more participation by customers, implementers, and contractors.

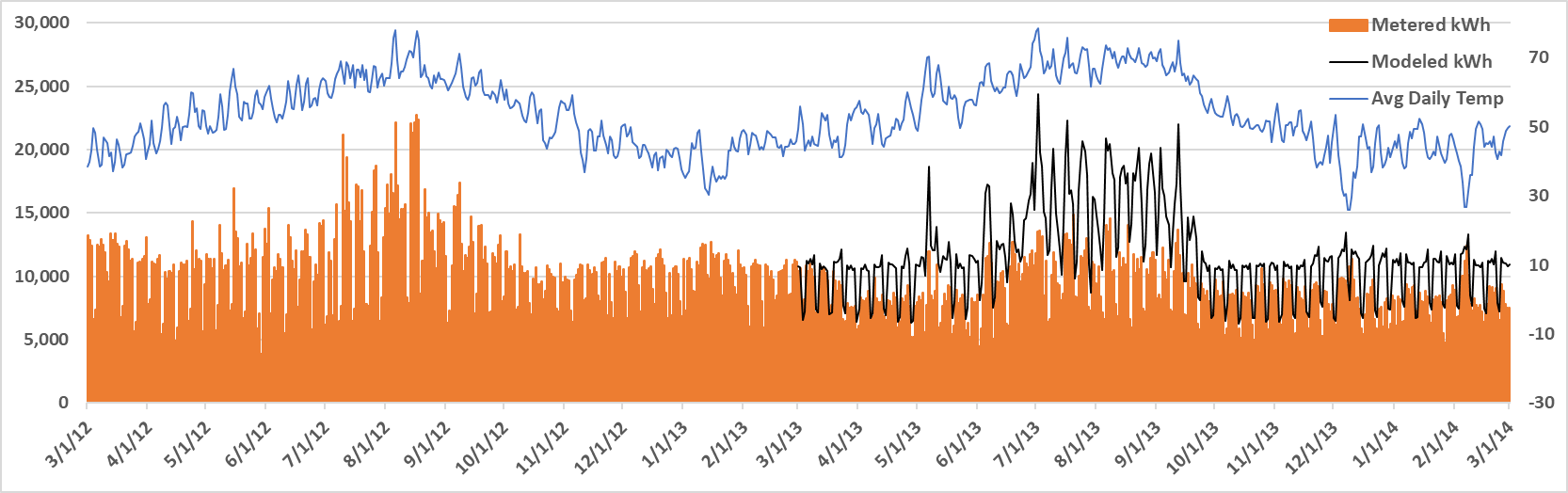
Methodology

The NMEC M&V Plan describes the requirements for each participating customer. Below we first describe the overall site-level NMEC process that governs a customer’s NMEC journey. This provides the context upon which the overall program M&V is based. While specific M&V plans for each participating customer are required, the program M&V Plan has a broader scope with additional elements including customer pre-screening, measure savings analysis, and lifecycle cost requirements.

Our approach to each site-level NMEC project is designed following the guidance on measurement and verification (M&V) plans LBNL provided to the CPUC[[1]](#footnote-1) (LBNL Guidance) and is compliant with the CPUC NMEC Rulebook version 2.0[[2]](#footnote-2), while integrating requirements set forth in A.17-01-013 for measure cost-effectiveness, estimated useful life, measure verification, and BRO measure maintenance plans. Our approach assesses each potential NMEC project prior to acceptance, collects the necessary information at key milestones of the process, and manages the inherent risks with meter-based methods. Figure 1 provides an illustration of our site-level NMEC project process, showing how customer engagement, measure development, and verification is integrated with the overall M&V process. This approach has been successfully implemented in several projects.

The chart shows how baseline use was adjusted to performance period conditions (black line) and how much daily energy use was reduced (gap between black line and orange bars). In each phase, several reports document key project requirements and milestones. Each program report is based on a template to assure all the required information is collected.

**Figure 1. NMEC Project Process**



Performance Period Activities

1. M&V Progress Check
2. M&V Report

Install Period Activities

3. Installation Report

Baseline Period Activities

1. Project Pre-Screening
2. Measure Feasibility Study with M&V Plan

Performance

Install

Baseline

Baseline Period

**Project Pre-Screening**. For each potential NMEC Program participant, the NMEC M&V Plan requires an initial site visit and discussion with the building owner to assess the facility baseline condition, the efficiency measure opportunities and their savings potential, and to ascertain the potential for non-routine events (described below) occurring in the baseline period or planned in the future. A year of energy use and weather data is collected, and an analysis completed to determine whether an energy model may be developed to meet the program’s goodness of fit and accuracy requirements.[[3]](#footnote-3) The pre-screening activity is used to determine whether the project is an acceptable site-level NMEC candidate.

**Project Feasibility Study**. A more in-depth assessment of potential energy efficiency measures is provided in the measure feasibility study. This step may include an ASHRAE level I or II energy audit. Individual measure savings and costs are provided and estimated useful life (EUL) is determined for each measure. Measures will be described according to custom measure categories, such as normal replacement, accelerated replacement, retrofit add-on, New, and so on. The feasibility study provides a description of the baseline systems and equipment, their operations, energy use, and the list of measures, with their savings, costs, and EULs. A weighted average EUL for the group of measures is determined based on CPUC guidance. The study is submitted to PG&E for approval and includes documentation of program influence and references the M&V Plan for the project.

The Site-Level M&V plan documents how savings will be determined. Following the LBNL Guidance and the NMEC Savings Procedures Manual,[[4]](#footnote-4) it describes the building, the potential savings, the meters and data required for NMEC analysis, what modeling algorithms were chosen to develop baseline energy models, their acceptance criteria, expected savings uncertainties, how Non-Routine Events (NREs) will be identified and their impacts determined, how savings will be reported, and how often. The NMEC Savings Procedures Manual provides templates for the M&V Plan and Savings Reports, which will be followed to capture all required information and provide complete descriptions of the savings analysis. Data, spreadsheets, and analysis code will be provided for technical reviewers and evaluators to understand how models were developed and assessed.

Installation Period

**Installation Report**. The NMEC M&V Plan requires measures to be verified as installed. Verification methods will include visual inspection with photos, receipt of contractor invoices and other cost information, and analysis of trend data from periods before and after measure installation, as available. Trend analysis provides direct evidence of the improvement in energy efficiency of building systems and equipment. These techniques for documenting measure performance may be used by building operators over time to demonstrate persistence. The installation report is submitted to PG&E for review and approval.

Performance Period

**M&V Progress Check**. Periodic checks will be made throughout the performance period at a frequency determined by individual projects to ensure that energy savings are accumulating. To complete the check, energy use data will be collected, and a savings-to-date analysis conducted. This task is very short in duration but provides valuable project insight. The analysis will show whether the savings are accruing as expected and identify the presence of any NREs that must be addressed. This is an internal TRC team activity. Any savings adjustments seen from this effort will be included in Captures to provide an accurate program reporting forecast.

**M&V Report**. The M&V report will document the raw data collected, preparations for its analysis, and analysis to determine savings, as described in the project’s M&V plan. It will be based on the savings report template provided in the NMEC Savings Procedures Manual. It will contain a narrative description of the models used, meter calibrations (as required), baseline period, model acceptance criteria, and savings analysis. All data, spreadsheets, and analysis code used in the analysis will be provided for technical review and evaluation. Savings reports will be issued at the end of the NMEC M&V period and will document program-claimed savings.

Additionally, the report shall discuss the “Goodness of Fit” statistics, model uncertainty, NREs, missing data and or “zeros”, as well as relationships between weather data and savings claims. The potential interactive effects, and possibility of fuel switching at the measure level, should also be included.

Software/Tools Employed

The TRC Team has developed an integrated suite of peer-reviewed and publicly available statistical data modeling algorithms to quantify savings achieved by energy efficiency projects following the NMEC approach. The suite enables the use of multiple modeling algorithms and quick assessment of their applicability and validity to determine the algorithm best-suited for each site. The diverse number of modeling algorithms available allow their application to a variety of building types. Moreover, the suite is extensible, designed to accommodate new modelling algorithms and other developments in the application of NMEC, including new capabilities based on kW Engineering’s own experience and research efforts.

The public-domain R programming environment is the NMEC analysis platform. R is a programming language and free software environment for statistical computing and graphics. It is supported by the R Foundation for Statistical Computing.[[5]](#footnote-5) Along with its integrated development environment RStudio, R is widely used by statisticians and data analysts in academic and professional environments. As an alternative to Microsoft Excel’s limitations with large volumes of data and advanced regression analysis, kW Engineering selected R and RStudio because of its focus on statistics, its wide use and support, no-cost and ready availability, and most importantly its transparency to anyone tasked with reviewing the analysis methods in NMEC programs. Use of the R code has streamlined all of the analysis required by site-level NMEC projects. With every project, the data and R code used for pre-screening and savings analysis is provided for technical review, along with instructions for setting up R, RStudio, and running the analysis. This process has been successful in multiple technical reviews to date.

The following are the key features of our M&V analysis portfolio:

1. **Transparency**: The algorithms are coded in the R programming language (an open source programming language), making them transparent and reviewable.
2. **Model Applicability Assessment**: All site data and models are assessed, visually and statistically, to ensure that data integrity is upheld, and the underlying regression modeling assumptions are met. These include:
   1. Linearity of data: The relationship between the predictor (e.g. temperature) and the predicted (energy use) is assumed to be linear.
   2. Normality of residuals: The residuals are assumed to be normally distributed. Residuals are the difference between the predictor and predicted values.
   3. Homoscedasticity: (homogeneity of residual variance): The residuals are assumed to have a constant variance.
   4. Independence of residuals: The residuals are assumed to be independent of each other.
3. **Quantification of the time value of energy saved**: The analysis is performed on PG&E AMI data or submetering (with short time intervals: 15 min or 1 hour), enabling time dependent valuation of savings.
4. **Timely feedback, reduced labor costs and improved accuracy**: The data-driven modeling algorithms are scripted in R and have run times in seconds. This upgrade from point-and-click M&V software reduces analysis time and provides detailed feedback on savings as they accrue. Moreover, scripting of the M&V data analytics provides a high level of computational accuracy while reducing the associated labor costs.
5. **Risk Quantification**: Data-driven modeling enables quantification of the uncertainty and risk associated with the savings projections and is calculated in accordance with the formulations provided in ASHRAE Guideline 14.

Analytical Methods

The following modeling algorithms are available in our analysis portfolio:

**Time-of-Week and Temperature (TOWT) Model**: The TOWT model[[6]](#footnote-6),[[7]](#footnote-7) is a linear regression-based load prediction method that has a time-of-week variable to characterize the load of each interval within a week, and a piecewise linear and continuous outdoor air temperature variable to describe the temperature dependency of the load. LBNL provided R code for the model in its GitHub Repository[[8]](#footnote-8) that included a weighting factor useful in demand analysis. Our team adapted the code to allow users to ‘disable’ the weighting factor and provide equal weight to all data points to remain in compliance with guidance provided by LBNL to the CPUC for NMEC programs.

**Time Only Model**: The Time Only model is a subset of the TOWT model, with the time-of-week variable as its sole predictor. As in the TOWT model, the time-of-week variable is developed to characterize the load for each interval within a week.

**Simple Linear Regressions with Outside Air Temperature and Change-Point Models**: The simple linear regressions and multi-parameter change-point models are based on the ASHRAE Research Project 1050-RP Inverse Modeling Toolkit[[9]](#footnote-9),[[10]](#footnote-10). It includes 2-parameter (linear regression), and 3-, 4-, and 5-parameter models.

**Heating and Cooling Degree Day Models**: Modeling algorithms based on heating degree days and cooling degree days are well known within the industry and have most widely been used in daily and monthly electric consumption/demand data analysis.[[11]](#footnote-11)

Key Data Points

The following data are required for site-level NMEC analysis:

1. ***Energy Consumption Data***: This can be sourced from a whole-building meter or a submeter, and should ideally be short interval data, i.e. 15-minute or hourly. The customer is requested to authorize access for our Program via PG&E’s ‘Green Button Connect My Data.’ Data from a facility owner’s submeters, along with calibration documentation, may also be requested to access energy consumption data.
2. ***Outside Air Temperature Data***: This can be sourced from the facility’s nearby weather station through National Oceanic and Atmospheric Administration (NOOA) or other similar weather data websites.
3. ***Normalized Weather Data***: This data can be sourced from the California Energy Commission’s CZ 2010 weather datasets, defined for 16 California climate zones, or the CZ 2018 weather dataset when it becomes available.
4. ***Operating Schedule Information***: If a building has more than one operating mode, this information will be needed to model the separate operating modes appropriately. Examples of operating modes include school’s holidays and summer sessions, different occupancy periods in office buildings, and so on.
5. ***Additional Predictor Variables’ Data***: For certain buildings, additional predictor variables, such as customers served, production rate, etc., may be essential to modeling the building’s energy use. For these cases, we will determine the appropriate predictor variables (through interviews with building owners) and request data access for modeling.

Data Collection Plan

As part of the participation requirement, customers must provide access to their utility data, or provide a year (minimum) of energy use data from their submeters. The program data collection plan is similar for each participant and includes the key data described above. For individual projects, data for estimating measure savings and measure verification analysis will be requested though a data request process.

The NMEC process requires data from multiple sources, and there are always challenges in obtaining reliable data for analysis. Metering and network connectivity issues may result in sporadic loss or erroneous energy data. Weather data files are notoriously ‘gappy’ over a few time intervals or may be missing weeks of data. Often data sets have repeated values for many time instances.

Customer-owned energy meters may be used provided they meet the meter type and accuracy requirements listed in the NMEC Rulebook Version 2. Non-utility meters have resolution issues, requiring use of longer time interval models. Additional independent variables beyond weather must be collected from the participant. These data sources must be reliable throughout the project. Their forms and recording time intervals must coincident with the energy data to be made useful for the M&V analysis.

Depending on the duration, the missing data may be ignored, interpolated from adjoining data points, filled-in using data from nearby weather stations, or the monitoring period may be extended. Each data cleaning step will be reported.

Good modeling practice requires that models be developed from a dataset that includes the maximum range of energy and independent variable values. Models should not be used for predictions more than 10% beyond the range (max – min) of independent variables used in the baseline period. Weather coverage factors, which describe how much of the range of baseline period temperature data includes the range of normalized conditions temperatures, will be part of the model assessment.

We will use the most complete and representative weather dataset for each savings quantification.

Precision of Program Savings Measurement

LBNL provided the “Guidance for Program Level M&V Plans: Normalized Metered Energy Consumption Savings Estimation in Commercial Buildings” document to the CPUC for the NMEC rulings. in section 3, a scenario analysis is recommended to demonstrate that the proposed modeling approach will produce results with acceptable levels of precision. The scenario analysis requires monthly billing data from a population of sites in order to proceed. Such a data request is not permitted in this solicitation. We note that research by LBNL under a PG&E Emerging Technology Project concluded that uncertainty estimation formulations for hourly and daily models underestimated the actual savings uncertainty, however they reliably estimated uncertainty for models developed from monthly data.

To assure that the TRC NMEC Program will provide savings estimates within the maximum allowable precision of 50% (90% confidence level), for each site-level NMEC project, we will estimate savings using monthly models by rolling up the energy consumption data to calendar months and performing the same analysis as we described above for daily or hourly models. We will do this only because the ASHRAE formula for savings uncertainty was shown to be valid for monthly models. Our process is to exclude projects that do not meet this 50% threshold from the NMEC program. As we complete more site-level NMEC projects, we will report the total program savings and savings uncertainty. The saving uncertainty will be reduced quickly at the program level as we add projects to the NMEC program, roughly by the inverse of the square root of the number of projects in the program.

We expect each site-level NMEC project in the program to generate savings at much lower levels of uncertainty than 50% and anticipate numerous participants in the program. Each of these factors will lead to an acceptably low program savings uncertainty, on the order of 10% or less.

The industry does need an accurate method to estimate individual site savings uncertainty with daily and hourly models. The collected data, modeling, and savings analysis in this program will enable further research in this area.

Approach to Ensure Adequate Monitoring in Reporting Period

Monitoring in the reporting period is critical for two reasons: 1) to assure savings are accumulating as expected, and 2) to periodically check for the occurrence of NREs, determine their cause, and remove their impacts from the final savings analysis. For each project, the TRC NMEC Program will run simple savings checks every two to three months during the performance period, as described earlier. Requests for participating customer energy data will be made, and the progress checks will be completed quickly using the R code. Customers find the progress checks helpful and useful for reporting energy savings successes to management.

Approach to Determining EUL Values

The feasibility study will identify and recommend energy efficiency measures for each NMEC project. Each measure’s estimated useful life (EUL) will be determined or approximated from Database for Energy Efficient Resources (DEER) records. The feasibility study will determine a weighted useful life for the recommended measures. After installation, this weighted useful life will be updated based on the actual measures installed and reported with the final savings report.

Adjusting for Non-Routine Events (NREs)

NREs can be short term, long term, or permanent changes in building energy use. They may be additions or subtractions of constant or variable loads. NREs occurring in the post-installation period are risks to the savings estimation. Savings progress checks will be used to identify the occurrence of NREs in the performance period. The following techniques to identify NREs with the metered energy use data will be used:

1. Visual Checks
2. Changepoint Analysis in R[[12]](#footnote-12),[[13]](#footnote-13)
3. Breakout Analysis in R[[14]](#footnote-14)
4. Anomaly Detection in R[[15]](#footnote-15)

Once identified, the facility owner will be contacted to determine the cause of the NRE. The facility owner will also be required to communicate the presence of an NRE, which will then be identified and verified in the meter data.

Techniques for addressing NREs vary depending on their significance and characteristics. If the NREs are found to last a short duration, such as a day, those short intervals will be removed from the dataset. Impacts of significant NREs defined as those lasting weeks or months will be quantified in terms of their magnitude of the impact on energy savings and project savings will be adjusted with project documentation will be noted accordingly. To manage costs, meter data analysis will first be used to resolve NRE impacts, followed by engineering calculations based on assumptions or based on data collected from the building through trends or data logging.

A short example of quantifying NREs with meter data is to develop a model using all data, except the data from the period in which the NRE occurred. We will use this model to estimate the ‘usual’ energy consumption in the period in which the NRE occurred. We will quantify the NRE by differencing the actual energy consumption and the estimated ‘usual’ energy consumption during the NRE period. Other methods we may employ are provided by BPA[[16]](#footnote-16) and LBNL.[[17]](#footnote-17)

Method of Determining Program Influence and Net-To-Gross

Program influence is determined and documented similar to any other custom measure. We believe that diligence in documentation and asking the right questions throughout the entire project development process is key to minimizing program free ridership. While there can be single showstoppers with a project, usually, free ridership is determined by examining several different attributes surrounding the project development and the customer’s decision to move forward.

Early screening for free ridership is extremely important. This reduces program costs by not developing ineligible projects but perhaps, more important, manages the customer’s expectations and program experience. The longer the development, the more time the customer has invested in program support. The earlier that a project can be identified as a free rider and cease development, the less negative impact on the customer. Free ridership screening is about understanding “what would have happened in the absence of the program” by asking open-ended questions to assess the state of the project at intervention and the customer’s motivations. Typical questions include:

* Timing of funding/budget allocation,
* Understanding the customer decision-making process,
* Current energy efficiency goals,
* Customer standard practice,
* Non-energy Benefits,
* Code requirements, and
* Equipment functionality and service.

The TRC NMEC Program will use the net-to-gross (NTG) ratio of 0.95 per CPUC Resolution E-4952. Should PG&E desire, we may also implement the self-report method to estimate the program NTG ratio, using the standard NTG question battery and analysis instrument used in the evaluation of the 2013-2015 nonresidential programs.[[18]](#footnote-18)

Savings vs. Normal Variations in Consumption

Screening projects to assure savings can be determined with reasonable uncertainties is good practice to ensure individual projects generate valid savings estimates. Since savings uncertainty is inversely proportional to the amount of savings achieved, the higher the savings, the less the savings uncertainty. The TRC NMEC Program will seek projects with a high level of savings but will not turn away projects with low savings as long as the savings can be determined with uncertainties that meet accepted statistical requirements, lower than 50% (of savings) at a 90% confidence interval. As described earlier, monthly models will be developed, and ASHRAE’s fractional savings uncertainty formulation[[19]](#footnote-19) used to estimate the uncertainty for each project’s estimated savings. The analysis will also yield the minimum detectable amount of savings, which will help assess how low savings can be and still meet the precision requirement. Each savings check will describe how savings are distinguishable from consumption variations, as based on this statistical analysis.

Entity Conducting M&V Activities

Most M&V analysis for the TRC NMEC program will be performed by our NMEC partner, kW Engineering. TRC internal engineers and engineering consultants will also conduct NMEC M&V activities as needed to support program goals.

Customer Incentive at Each Project Stage

The customer incentive will utilize the flexible incentive structure which provides a variable incentive based on project specifics. The following major project milestones will be used to trigger customer incentive payment:

1. **Project Feasibility Study** –
   * No customer incentive is paid at this time.
2. **Installation Report** –
   * TRC will distribute customer incentives upon PG&E review and approval of the installation report based on a portion of meter data.
3. **M&V Report –** 
   * TRC Program design does not true up the customer incentive based on the full M&V period.

Method(s) and tools utilized in the calculation of incentives and/or compensation at each stage of compensation

Methods and tools are described in “Analytical Methods” Section of this document.

The customer incentive will be calculated with the Flex Incentive which is the same manner as other custom measures. The Flex Incentive utilizes the customer payback requirement to adjust the incentive such that the incentive is “just enough” to reach the funding approval criteria. A minimum incentive level will be employed to keep the customer engaged throughout the process.

Eligibility Criteria and Target Population

All agricultural customers with commercial type building spaces eligible for AESAPs are eligible for the NMEC savings platform. The following are Agricultural buildings that are eligible for NMEC as of the creation of this agreement:

* Greenhouses (excluding growing spaces),
* Indoor Horticulture (excluding growing spaces),
* Offices within the Agricultural facility,
* Non-refrigerated storage/warehouses within the Agricultural facility,
* Refrigerated warehouses, and
* Shipping/receiving areas within the Agricultural facility

The target population includes those customers that would likely meet the pre-screening criteria. Refrigerated warehouses and wineries are likely to have energy consumption patterns that meet the NMEC pre-screening criteria. Customers in other segments may be targeted throughout the Program.

Quality Assurance Practices

Several quality assurance and quality control steps will be taken to assure savings estimations are reliable, transparent, and repeatable. These have been described above. In addition, other steps have been included in the process to assure the savings are due to the measures and not NREs. These include:

* Measure verification, based on site inspections, photos and trend analysis,
* Periodic tracking of savings progress throughout the reporting period
* Check-ins with building owners and operators when anomalous energy use is detected.

Report templates will be used throughout the NMEC project process, to assure the correct information is collected and analysis is properly explained.

Data quality checks are used to assure data integrity for each project. These include graphical checks for outliers, gaps, and repeated values, logical checks to assure the data makes sense, and statistical checks on distributions of data.

Each model will be evaluated by checking the assumptions underlying the modeling algorithm, such as normal distributions of points and patterns in the residual plots

Providing raw data, prepared data, and R code as part of M&V Plans and Savings Reports to assure all data and analysis is completely transparent and reviewable. To date, this process has been successfully implemented in two NMEC projects, where reviewers were able to set up the R environment and run our analysis on the prepared data sets to get the same results.

We will provide internal quality assurance by requiring each report be reviewed by an engineer not involved in the project. Comments will be addressed, and corrections made to each report prior to their delivery. All data and analysis R code for the specific project will be provided with each savings check. The TRC team will support every technical review and evaluation process.

To be noted, that no referenced document herein is to be construed as to supersede the CPUC NMEC Rulebook (latest version), but only to inform and enhance the project savings claims.

1. Guidance for Program Level M&V Plans: Normalized Metered Energy Consumption Savings Estimation in Commercial Buildings, version 1.0, March 1, 2018, available at: <ftp://ftp.cpuc.ca.gov/gopher-data/energy_division/EnergyEfficiency/RollingPortfolioPgmGuidance/LBNL_NMEC_TechGuidance_Draft.pdf>. [↑](#footnote-ref-1)
2. Rulebook for Programs and Projects Based on Normalized Metered Energy Consumption, version 2.0, January 7, 2020, available at: <https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442463694> [↑](#footnote-ref-2)
3. Per the “Guidance for Program Level M&V Plans: Normalized Metered Energy Consumption Savings Estimation in Commercial Buildings” guidance document provided CPUC by LBNL for the NMEC rulings, these criteria are: CV(RMSE) < 25%, NMBE < 0.5%, and R2 > 0.7, where CV(RMSE) is the coefficient of variation of the root mean squared error (a measure of model random error), NMBE is the net mean bias error (a measure of model bias error), and R2 is the coefficient of determination (an indication of how well the independent variables, e.g. temperature, ‘explains’ the dependent variable, e.g. energy use). [↑](#footnote-ref-3)
4. Normalized Metered Energy Consumption Savings Procedures Manual. SCE Emerging Technology Project ET15SCE1130, available at: <https://www.etcc-ca.com/reports/normalized-metered-energy-consumption-savings-procedures-manual>. [↑](#footnote-ref-4)
5. R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/. [↑](#footnote-ref-5)
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7. Price, P., 2010. Methods for analyzing electric load shape and its variability. Lawrence Berkeley National Laboratory Report LBNL-3713E. [↑](#footnote-ref-7)
8. Touzani, S., RMV2.0 (2018), Github repository, <https://github.com/LBNL-ETA/RMV2.0> [↑](#footnote-ref-8)
9. Kissock, J. K., Haberl J.S., Claridge, D.E., 2002. Development of a Toolkit for Calculating Linear, Change-point Linear and Multiple-Linear Inverse Building Energy Analysis Models. [↑](#footnote-ref-9)
10. Killick, R. and Eckley, I., 2014. changepoint: An R package for changepoint analysis. Journal of Statistical Software, 58(3), pp.1-19. [↑](#footnote-ref-10)
11. Multiple websites describe the methodology, for example: <https://www.degreedays.net/calculate-energy-savings> [↑](#footnote-ref-11)
12. Killick, R., Fearnhead, P. and Eckley, I.A., 2012. Optimal detection of changepoints with a linear computational cost. Journal of the American Statistical Association, 107(500), pp. 1590-1598 [↑](#footnote-ref-12)
13. Killick, R. and Eckley, I., 2014. changepoint: An R package for changepoint analysis. Journal of Statistical Software, 58(3), pp.1-19. [↑](#footnote-ref-13)
14. James, N.A., Kejariwal, A., Matteson, D.S., 2014. Breakout Detection via Robust E-Statistics, Github repository, <https://github.com/twitter/BreakoutDetection> [↑](#footnote-ref-14)
15. Vallis, O.S., Hochenbaum, J., Kejariwal, A., 2014. Anomaly Detection Using Season Hybrid Extreme Studentized Deviate Test, Github repository, <https://github.com/twitter/AnomalyDetection> [↑](#footnote-ref-15)
16. SBW Consulting, April 30, 2018, Potential Analytics for Non-Routine Adjustments. Prepared for Bonneville Power Administration [↑](#footnote-ref-16)
17. <https://github.com/LBNL-ETA/nre> [↑](#footnote-ref-17)
18. 2013-2015 Program Performance Assessment of the Nonresidential Downstream Programs. Submitted to CPUC by Itron, December 2017. [↑](#footnote-ref-18)
19. ASHRAE Guideline 14-2002, Appendix B. Fractional savings uncertainty for models with uncorrelated and correlated residuals. [↑](#footnote-ref-19)